Improving Energy Efficiency Improves Smoke Safety and Occupant Comfort

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ABSTRACT

Energy efficiency, smoke safety, and occupant comfort are important building management issues. One pervasive problem connects them all: the challenge of controlling air infiltration, exfiltration, and air movement within the building.

Four key factors affect building air movement: overall envelope tightness, climatic conditions, the HVAC system, and the orientation and exposure of the building. This article details the effects of controlling air movement on achieving improved energy performance, better smoke control during a fire, and benefits of improved comfort for building occupants.

Energy efficiency improvements are reported using examples of actual buildings. Details are given of how increased air tightness, combined with properly designed and controlled ventilation, can improve thermal performance, reduce short-circuiting of conditioned air, and improve humidity control. A recent report by The National Institute of Science and Technology confirming the energy efficiency contribution of air barriers in the building envelope will be discussed and reference will be made to the coming publication of an ASHRAE 90.1 update, which includes air barriers for the first time.

Examples of fatal incidents demonstrate the connection between smoke movement within a building during a fire and a leaky building envelope.

Comfort improvements achieved through better air movement control include not only better thermal performance from HVAC systems, but also reduced transfer of irritants such as noise, cigarette smoke, odors, dust, dirt, flies, and other insects.

The author takes the audience through a practical step-by-step approach to correcting problems using case studies.

EVERYTHING IS CONNECTED

In any building, energy efficiency, smoke safety, and occupant comfort are all connected with each other through one common phenomenon: air movement. If you control air movement in a scientific and organized manner, you can reduce energy bills, the danger of smoke spread during a fire, and complaints about occupant comfort.

All three are important building management issues, but are rarely discussed in the same meeting. Perhaps the reason is because most peoples' understanding of how air (and that includes smoke-laden air) moves around inside a building as well as into and out of it is very limited. If we tackle the three issues simultaneously, there is a good possibility that the energy savings will quickly pay for the smoke safety and comfort improvements.

HOW TO REDUCE UNCONTROLLED AIR MOVEMENT

Sealing air leaks in any kind of building has to start with an assessment. Cracks, gaps, leaks, and holes are easily made visible with an air leakage detector or smoke pencil. Sometimes a large-scale depressurization fan is used to create negative pressure in the building and increase the visibility of leaks. In some instances, infrared thermography from outside the building can show patterns of air leakage. Energy saving potential is analyzed using EC 128/ALCAP software.

Once the air leakage pathways have been identified throughout the building, including their exit and entry points, the building envelope specialist can prepare the air barrier continuity plan. This addresses air sealing in five critical areas. First, the top of the building; second, the bottom; third, the vertical shafts; fourth, the outside walls and openings; and finally, compartmentalizing by sealing internal air leaks.

The pathways that are sealed to create barriers to smoke and improve energy efficiency include:

- Roof/wall intersections
- Mechanical penthouse doors and walls

- HVAC equipment
- Roof penetrations
- Underground parking access doors
- Exhaust and air intake vents
- Soffits and ground floor access doors
- Service penetrations
- Sprinkler hanger penetrations
- Inspection hatches
- Slab/wall intersections
- Stairwell fire doors
- Fire hose cabinets
- Elevator cable holes
- Elevator room doors
- Garbage chute perimeters and access hatches
- Hallway pressurization grille perimeters
- Elevator shaft smoke control grilles
- Fire exit signs
- Vented mechanical rooms
- Garbage compactor rooms
- Emergency generator rooms
- High voltage rooms
- Shipping docks
- Workshops
- Door and window trim and weather-stripping
- Baseboards
- Baseboard heaters
- Electrical receptacles

PROVEN ENERGY SAVINGS

According to the Department of Energy, uncontrolled air movement wastes up to 40 percent of a building owner's energy dollars. Air barrier retrofits have delivered proven energy savings cost-effectively for more than three decades.

Computer simulations have been developed that show how air infiltration affects an existing building's HVAC system. These suggest that reduced air infiltration appears to reduce total energy use by about 20 to 25 percent. How those numbers are used is up to building owners

and the manner in which they choose to execute their energy efficiency strategy.

Building envelope upgrades performed a few years ago for a Syracuse, NY, school district meant savings estimated at US$52,000 a year. Niagara Mohawk Energy Inc. (NME) of Syracuse, NY, managed the project. NME is a company that conducts energy audits and develops efficiency programs, markets natural gas and electricity, and provides on-site generation and co-generation services.

NME brokered air barrier continuity retrofits for the Liverpool Central School District—one of the Metropolitan Syracuse area's fastest-growing school districts—a project involving extensive energy conservation measures at 17 facilities. A measurement and verification process confirmed the forecasted savings, and calculated a simple payback of five years.

Arvin Air Systems is a company based in Stoney Creek, Ontario, that specializes in HVAC systems. In 2002, its engineers helped reduce an industrial building's million-dollar annual energy consumption.

They attacked the problem using three major initiatives. First, they reduced the amount of mechanical exhaust in the building to building code and ASHRAE standards. The building was exhausting more air than needed and creating negative pressure. Correspondingly, the heated makeup air was reduced because less exhaust meant less air had to be replaced. Finally, the building envelope was sealed, including roof openings, window insulation, weather-stripping, and new mechanization of some frequently used doors to reduce the amount of time they stayed open.

The project cost $300,000, which was returned through energy savings in one year. The project reduced the annual energy bill to $750,000, which is a marked difference from the building's prior consumption.

Performance contractors, or energy service companies, as they were then known, saw the benefit of air sealing a long time ago. In 1994, the Muskoka Board of Education signed a guaranteed 120-month performance contract with Honeywell to manage energy in 24 schools. The entire program was paid out of energy and operating cost savings. One of the schools, Gravenhurst High School, received an air barrier retrofit that cost $6,740, with an anticipated payback of 5.6 years. Yet once the work was completed, natural gas consumption was reduced 692.67 million Btu for savings of $4,893 in the two coldest months of the 1995/96 winter.

SMOKE SPREAD DURING A FIRE

The Ontario Association of Architects and CMHC joint publication *Fire Safety in High-Rise Apartment Buildings**, written by Ken Richardson of Ken Richardson Fire Technologies Inc., offers some alarming statistics on what really causes deaths. It is nearly always smoke and it's usually in the higher floors. Why? Because once a fire starts, smoke travels unbelievably quickly upwards through a high-rise.

In 1993, a terrorist bomb exploded in the underground parking garage of the World Trade Center. Smoke spread from three floors below ground all the way up to the 84th floor in just 12 minutes.

Richardson writes that a study of representative Canadian high-rise fires illustrates a number of points that designers should consider. Among them are:

- Unsuppressed fires in high-rise buildings generate large quantities of smoke that can spread vertically or horizontally through the building even if the fire is contained to only one room or apartment.
- Vertical smoke spread is exacerbated by wind and stack effect, which occurs when the building's inside temperature is greater than the outside.
- In multiple death fires in residential high-rise buildings, many fatalities occur in the egress routes (stairways and corridors) due to smoke from a fire elsewhere in the building.
- In apartment fires with doors left open or burned-through, smoke will spread to the corridors, shafts, and upper levels.

Two examples of fatal fires: In 1992, a fire began in a 9th floor apartment of 250 Davenport Road, a 25-story apartment building (without sprinklers) in Toronto. The occupants escaped, but left the door open. The fire was contained to the apartment of origin. Within ten minutes of the alarm, smoke spread to all floors above the ninth and to the exit stairwells causing one fatality†.

In 1995 a fire began on the 6th floor of 2 Forest Laneway, a 30-

*Any building six stories or more in height.

†Goodyear, D. and Harper, R., Fire Investigation Report—High-rise Buildings, National Fire Protection Association, Quincy, MA, 1994.

story reinforced concrete apartment building in Toronto. The occupants escaped, but left the door open. The fire was essentially contained to the unit of origin. Smoke spread rapidly throughout the building causing six fatalities near the top of the two stairwells.*†

Although these and other examples address buildings not built to current code requirements, simply complying with a building code does not necessarily provide optimum life safety.

A complex series of pipes, ducts, cables, and conduit, including fire protection water supplies, run vertically and horizontally through these buildings. Smoke travels rapidly through any penetration in floors or walls created for these services but left unsealed…even though these penetrations are required by code to be fire-stopped. Most importantly, it travels through all rooms that have open vents and are therefore not separated into "fire and smoke compartments."

One strategy to control the fire and smoke spread process is known as control by construction. This includes the stability of structural elements against fire attack and fire "compartmentalization" with rated walls and floors. These same construction elements may not be effective, however, in controlling the spread of smoke if there are cracks and openings in them such as for doors and windows, penetrations for ducts, cables, and piping. Often, these openings have a significant effect on fire and smoke spread, so architects must exercise special care in their design.

FCS Fire Consulting Services Ltd., of Innisfil, Ontario, accepts that building owners and managers face difficult responsibility and liability issues around this subject. If complying with building and fire codes is not enough, what is a property manager or condominium board to do?

FCS is concerned that although building codes call for fire sealing of penetrations and smoke stop measures to be implemented at time of construction, there's too little enforcement of continued compliance under the fire code.

Owners and managers would like to be able to say: "we have done everything we can do," but the definition of "everything we can do" is

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*Proulx, G., et al., Study of the occupants' Behavior During the 2 Forest Laneway Fire in North York, ON, January 6, 1995, Internal Report No. 705, Institute for Research in Construction, National Research Council of Canada, 1995.

†Fire Investigation Report, Residential High-Rise, Six Fatalities, North York, ON, January 6, 1995, National Fire Protection Association, Quincy, MA, 1995.

unclear. Reducing smoke spread in high buildings is shown to be the most critical aspect of fire protection, so at the very least, we should do as much as we can, in addition to mechanical means, to control the flow of air within, into and out of the building, and contribute to better control of smoke spread.

Property managers and condominium boards should realize that it is essential for all buildings, particularly older ones, to have a fire separation review every few years. Service alterations, building aging effects, or even residents performing their own plumbing work can damage fire separations. Although regular maintenance can address these areas, significant or numerous breaches will compromise smoke containment during a fire emergency.

IMPROVING OCCUPANT COMFORT

Controlling air movement has many side benefits. Improving comfort for people who live or work in a building not only makes for happy occupants; it reduces stress for building managers who have fewer complaints to deal with.

Problems around thermal discomfort are most common; typically they are about drafts and cold spots. Reducing irritants such as noise, cigarette smoke, pests, flies, dust, and dirt will get gratitude from the majority. A good air leakage control strategy will solve all of these.

APARTMENT BUILDING RETROFIT COMBINES ENERGY EFFICIENCY AND SMOKE SAFEY

The owners of Forest Laneway, a three-tower, 1000-plus unit apartment complex in Toronto, faced steadily escalating energy costs, 27-year-old heating and air conditioning systems that had reached the end of their useful life, and spiraling maintenance requirements.

Fortunately, their consulting team recognized the need to review building envelope performance and brought in the author's contracting company.

Stack effect in these buildings was found to be extreme and it was causing comfort problems, particularly with lower units. The contractor informed the building owners that controlling air movement caused

by stack pressures would improve smoke and odor control, energy efficiency, and occupant comfort.

At the top of the building, the contracting team isolated and compartmentalized mechanical rooms by weather-stripping doors, fire stopping appropriate penetrations through rated walls, reducing the size of cable holes in the elevator shafts and door controller cable penetrations, as well as bus bar and other electrical penetrations through the floor of the elevator rooms.

At the bottom of the building, the team effectively sealed the many penetrations found in the underground parking areas. Doors were weather-stripped and a large number of unsealed cable conduit duct and pipe penetrations and gaps between the block infill and slabs were sealed.

Vertical shafts, where doors with two-inch gaps underneath were prevalent, were weather-stripped. This decoupled floor-to-floor and reduced air movement. This activity had to be balanced with the need of people on upper floors to open doors.

Other areas sealed included fire cabinets, garbage disposal rooms, electrical rooms, and other service shafts. The highest quality durable weather-stripping, together with appropriate one- and two-component polyurethane foam and fire-stopping sealants, were used throughout the project.

The combined efforts of the contractor and a major HVAC upgrade resulted in big savings.

"Our goal was $200,000 a year," says Evelyn Visconti, Vice President, Residential Division, for the Tandem Group, property managers for Forest Laneway. "We did much better in our first year and considerably surpassed projections. In fact, we might very well reduce our estimated payback target."

LOOKING FORWARD

Performance contractors, energy management consulting firms, incentive-providing utilities, and government departments are using documented energy savings with increasing frequency—along with ALCAP calculations—to make decisions in favor of envelope upgrades.

Currently, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Envelope Sub-

committee is looking to update the building air leakage requirements under Addendum z to the 90.1-2004 version of the standard to include a continuous air barrier system.

Energy efficiency tax incentives from the United States federal government under the Energy Policy Act of 2005 include deductions up to $\$1.80/ft^2$ for HVAC and envelope performance improvements of 50 percent above ASHRAE 90.1-2001, helping to create another financial justification for air sealing retrofits.

ABOUT THE AUTHOR

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